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ONE SPACE PARK • REDONDO BEACH, CALIFORNIA

ATLAS/CENTAUR PROGRESS REPORT

8414-6108-RU-000

30 September through 11 October 1963

T. W. Layton [1963] 10p

Prepared for

Lewis Research Center NASA
Cleveland 35, Ohio

[X] OTS

[2]

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SPACE TECHNOLOGY LABORATORIES, INC.

INTEROFFICE CORRESPONDENCE

9351.6-431

TO: B. F. Cohlan

CC:

DATE: 10 October 1963

SUBJECT: Bi-Weekly Progress Report - Vehicle Dynamics, Guidance and Controls (30 September through 11 October 1963

FROM: T. W. Layton

1.0 VEHICLE DYNAMICS PROGRAMS

The package containing the Root Locus and Eigen Eight computer programs has been shipped to and received by LeRC. These programs have been prepared for the IBMAP IBM routine and as such are directly useable at LeRC. The special STL input-output format has been converted also to the new language. As directed by LeRC, work on the Combined Modes Program was begun rather than finishing the remaining two portions, including the frequency response of the 3370 routine. No report on the results of AC/2 check case runs has been received from LeRC.

2.0 CONTROLS SYSTEMS ANALYSIS

2.1 AC/3 Booster Analysis

A method has been established for incorporating the non-linear hydraulic actuator in the analysis. In the low frequency slosh analysis (to 10 rad/sec) the actuator will be represented by a first order lag which matches the lower portion of the frequency response of the non-linear actuator describing function. The value of the lag is a function of engine amplitude and frequency of interest. In the high frequency bending analysis (above 10 rad/sec) the actuator will be represented by a fixed third order transfer function which approximates the upper portion of the frequency response of the actuator describing function for large engine amplitudes. The effect of varying engine amplitude on system stability will be studied by making system phase and gain adjustments which correspond to the discrepancy in phase and gain between the non-linear actuator describing function and the third order transfer function which will be used in the analysis.

The experimental, non-linear slosh damping data for the Centaur LOX tank has been received and has been scaled and converted to the right form. Preliminary results of the slosh analysis indicate that a possible slosh limit cycle during sustainer flight will cause a negligible engine amplitude of less than 0.1 degree sloshing driving. The flight period before booster engine cutoff is presently under investigation.

Preliminary results of the bending analysis indicates that the GD/A proposed quadrative filter will provide more than sufficient stability margin at the first bending frequency during the entire booster flight period.

3.0 GUIDANCE SYSTEM ANALYSIS

A memo which describes the IMU primitive to be incorporated into the Centaur Simulation Program has been written and programming has begun.

The first closed loop simulation of the direct ascent trajectory with the constants computed by STL is presently under evaluation and noted programming deficiencies are being corrected. Another closed loop simulation of the same direct ascent trajectory, employing the new guidance equations and constants described in the GD/A 63-0490 report, dated 21 June 1963, is presently under evaluation.

Interpretive computer simulation runs are being made (open-loop) with the final AC-2 flight computer program (AC2I2R3). This program includes the final SCATE III pre-flight program, in addition to the final AC-2 (Revision 3) in-flight program.

4.0 GUIDANCE T AND E PROGRAM

4.1 Precision Centrifuge Test

During the week of 23 September, STL attended a meeting in St. Petersburg to review a second draft of the Honeywell precision centrifuge test procedure. STL reviewed the first draft of this document in August. STL's review of the first draft was submitted to NASA/LeRC in Reference (1).

At the September meeting STL recommended a number of changes to the revised test procedure. Most of these recommendations pertained to the proposed method of testing and to the scheme that will be used to analyze centrifuge test data. STL's recommendations were favorably received and will be incorporated in a second revision of the test procedure. Minutes of the September meeting will be published by Honeywell.

STL will reduce the data obtained on the precision centrifuge (at Holloman) by means of computer routines that are available at STL. The use of existing STL computer routines may save the expense of preparing similar programs at both GD/A and Honeywell.

5.0 ACCELEROMETER REBALANCE LOOP DYNAMICS

STL attended a meeting in San Diego during the week of 30 September to review the dynamics of the accelerometer rebalance loop. At this meeting, Honeywell presented the analysis that led to the recent redesign of the rebalance loop. Honeywell also presented test data obtained with modified hardware.

It was evident from the Honeywell presentation that a great deal of progress has been made in correcting the problems that existed in the rebalance prior to the redesign. (The most serious of these was the sensitivity of the loop to both internal and external noise.) The most serious remaining problem is the fact that the loop will saturate when subjected to sinusoidal vibration of 2.7 g zero to peak (applied at the base of the platform mounting bracket). Honeywell has proposed a further modification that will raise this saturation level above 3.0 g zero to peak.

STL is preparing a commentary on the material presented by Honeywell. This document will be submitted to NASA/LeRC within the next week.

6.0 PLATFORM GIMBAL BEARING PROBLEM

STL has completed a preliminary analysis of the inertial platform gimbal bearings. These bearings present a potential reliability problem because of the abnormally light bearing pre-load (5 pounds for the resolver bearings and 0.5 pounds for the torque motor bearings) and the relatively low maximum torque (10 inch-ounces) available at the torque motors. The preliminary STL analysis has been forwarded to NASA/LeRC in Reference (2).

The STL analysis has indicated that the gimbal bearings will unload during flight and as a consequence may brinnel. It would appear that the bearing reload should be increased.

The STL analysis has been limited by lack of information. A request for the information required to complete this analysis was forwarded to GD/A in Reference (3).

7.0 ELECTRO-INTERFERENCE

At the STL-LeRC bi-weekly meeting of 3 October, STL reviewed the current status of electromagnetic interference testing. STL reviewed the test of a -3 computer that was recently completed at San Diego and discussed the guidance system tests which are scheduled to begin within the next two weeks in St. Petersburg. STL also discussed the missile tests which have been performed at San Diego and the electromagnetic interference tests which are planned for AC-2 at 36A. STL recommended several changes to the AMR tests. Those recommendations have been documented in Reference (4).

STL also reviewed a number of electromagnetic interference problems that have been encountered in equipment other than the guidance packages. This material has been submitted to NASA/LeRC in Reference (5).

8.0 ACCURACY ANALYSIS

At the GD/A-LeRC Program Review Meeting of 4 October, STL presented an interim report of the guidance system accuracy analysis which STL is preparing. The material presented was similar to that presented at the STL-LeRC bi-weekly meeting of 28 August (see Reference (6)).

Following the STL presentation, Honeywell indicated that their engineers are preparing a similar analysis. Honeywell also indicated that many of the STL estimates (of the magnitude of error sources) did not make use of test data which are available to Honeywell.

An action item was given to Honeywell and STL to review jointly and in detail all of the available guidance system test data which are pertinent to accuracy analysis. The purpose of this assignment is to eliminate much of the misunderstanding and confusion that has existed in this area in the past.

9.0 SLED TEST

9.1 Sled Vibration Environment

Considerable effort has been expended in review of the Centaur sled vibration environment, particularly the results of the dummy vibration runs and the applicability to the actual sled run and Centaur environment.

9.2 Sled Test Simulation (ECRP)

The number of σ_{K_i} terms has been reduced to four downrange accelerometer terms and two gyro terms. Initial results, using a constant tracking error and reduced noise tape, show good recovery of two accelerometer terms and both gyro terms. Additional runs will be made with modified parameters to determine effect on recovery capability.

10.0 FLIGHT TEST

Work has progressed on the STL internal data handling plan for Centaur Flight Test Data. The STL flight data requirements have been forwarded to NASA, (Reference (7)). Further, an outline of the data handling procedure has been written and is being used as a guide to assemble the final plan.

T. W. Layton

TWL/js

References: (1) 8414-6069-TU-000, "Review of Minneapolis-Honeywell Precision Centrifuge Test Procedures", from T. W. Layton to H. G. Hamby, dated 8 August 1963

(2) 9304.3-369, "Centaur Missile Guidance System Inertial Platform Bearing Problem Analysis", from T. W. Layton to W. R. Dunbar, dated 2 October 1963

(3) 9304.3-370, "Information and Data Required to Complete Analysis of Centaur MGS Inertial Platform Gimbal Bearing Problem", from T. W. Layton to D. Geyer,, dated 2 October 1963

(4) 8414-6101-TU-000, "Electromagnetic Interference Test at AMR", from T. W. Layton to J. C. Nettles, dated 1 October 1963

(5) 8414-6100-TU-000, "Component RFI Tests and Present Compliance Status", from T. W. Layton to J. C. Nettles, dated 1 October 1963

(6) 8414-6077-TC-000, "Minutes of LeRC/STL Bi-weekly Meeting of 21 August 1963", T. W. Layton to B. F. Cohlan, dated 28 August 1963 (Confidential)

(7) 9351.8-272, "Final Data Requirements for AC-2", from T. W. Layton to R. A. Flagge, dated 3 October 1963

SPACE TECHNOLOGY LABORATORIES, INC.

INTEROFFICE CORRESPONDENCE

63-9712.3-41

TO: B. F. Cohlan

CC: ~~See Distribution~~

DATE: 9 October 1963

SUBJECT: BI-WEEKLY REPORT FOR PERIOD 30 SEPTEMBER THRU 11 OCTOBER 1963 ATLAS/CENTAUR PROGRAM

FROM: M. E. White MEW

BLDG. R-1 ROOM 1028A EXT. 23903

Approved: A. Kaplan

A. Kaplan

Study Area 2: Launch Wind Constraints Study

The digital flight simulations for the ten year record of AMR March wind soundings have been reviewed. Each flight simulation was defined as a success or a failure if the wind induced loads were within or exceeded the vehicle capabilities. The statistical analyses have been completed and they established the probability of at least one success during any 1, 2, 3 . . . 6 consecutive day period. The statistical analyses also determined the probability of at least one success in a 1, 2, 3 . . . 6 day period following a "failure" sounding.

Flight simulations have been completed for all of the wind soundings for the month of March 1962 using the standard pitch program. Evaluation of the results revealed that only five flight simulations were successful. Previous flight simulations of the same March 1962 soundings with the biased pitch program revealed that twenty simulations were successful. Such results confirmed the choice of the biased pitch program for this study as a means to increase the vehicle launch availability.

A report is presently being prepared which summarizes the results of this study. This will be presented and discussed at the next technical meeting in Cleveland on 16 October.

MEW:jb

SPACE TECHNOLOGY LABORATORIES, INC.

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INTEROFFICE CORRESPONDENCE 9861.6-210

TO: B. F. Cohlan CC: DATE: 10 October 1963

SUBJECT: CENTAUR Biweekly Progress Report - Mission Analysis - 30 September to 11 October 1963

FROM: R. J. Lowell
BLDG. E ROOM 3010 EXT. 24070

At the request of the Propulsion Laboratory an effort is being made to determine the payload increment which could be obtained by substitution of RJ-1 fuel for the currently used RP-1 propellant.

The results of the booster shaping study have been written up and the memorandum is in the process of being published. A companion study of the effects on payload capability of the shaping employed during sustainer burning is being initiated.

Three sigma dispersions of selected powered flight parameters from the nominal AC-2 trajectory have been simulated. These include $\pm 3\sigma$ dispersions in CENTAUR thrust and ISP, booster thrust and ISP, sustainer thrust and ISP, booster pitch factor and platform attitude steering vectors. All of these perturbed trajectories achieve acceptable Earth orbits.

The AC-2 simulation is being updated to incorporate changes from the 21 September 1963 GD/A Monthly Status Report. In addition, the new CENTAUR propulsion model is undergoing final checkout before incorporation into the AC-2 simulation.

R. J. Lowell /jh

R. J. LOWELL

RJL:db

S P A C E   T E C H N O L O G Y   L A B O R A T O R I E S ,   I N C .

INTEROFFICE CORRESPONDENCE

9730.3-63-169

TO: B. F. Cohlan   CC: See distribution   DATE: 9 October 1963

SUBJECT: Atlas/Centaur Bi-Weekly Progress Report
Propulsion Support
30 September to 11 October 1963

FROM: B.B. Levitt

I. PROPULSION PERFORMANCE

A. RL10 Engine Performance

RL10A-3 influence coefficients have been generated from the latest Pratt and Whitney regression equations (RL10 Field Operations Memorandum No. 21, Revision No. 2 dated 29 July 1963), and are presently being programmed and checked out in the "Centaur Propulsion System Simulation Model" for use in the AC-2 post-flight analysis technique.

B. Centaur Post-Flight Analysis Program

Programming of the "Centaur Propulsion System Simulation Model" in the 2-D trajectory program has been completed. Several checkout runs of the program have been conducted with satisfactory results. However, final program check-out will not be completed until the latest RL10A-3 influence coefficients have been programmed (A. above). STL Memo 63.9731.9-24, "Centaur Propellant Tank Sensors," dated 1 October 1963 was published, which presents a discussion on the need for volumetric flow rate data in post-flight analysis, with respect to the Propulsion Laboratory's previous recommendation to LeRC that additional propellant level sensors be installed in the Centaur vehicle.

C. MA-5 Booster Performance

Altitude influence coefficients were generated for the uprated MA-5 booster using RP-1/Flox, and forwarded to the Mission Analysis Section in STL Memo 8414-6090-MU-000, "MA-5 Uprated Booster Influence Coefficients for 20 percent Fluorine Additive," dated 25 September 1963.

D. RJ-1 Fuel Study

Comparison of the latest RJ-1 and RP-1 performance gains have been completed and the results published in STL Memo 8414-6102-TU-000, "Revised Payload Gain Obtained by RJ-1 Fuel in the Atlas/Centaur Propulsion System," dated 4 October 1963. Comparison results indicated an approximate payload increase of only 15 pounds for RJ-1 over RP-1 fuel, as opposed to a previously determined 73 pound gain. The decrease from the original payload gain is due to a decrease in the specific impulse of the booster and sustainer engines using RJ-1, as indicated by the latest Rocketdyne RJ-1 influence coefficients.

E. AC-2 Pre-Flight Trajectory

Comparisons between the AC-2 Pre-flight trajectories calculated by GD/A and STL have been completed, and the results published in STL Memo 8414-6092-MU-000, "Comparison of the STL and GD/A Propulsion Simulations in the Pre-flight Trajectories for AC-2," dated 24 September 1963. From comparison of the simulations it was determined that GD/A used a sea level booster and sustainer model with nominal MA-5 engine class propulsion performance values. In contrast, STL used an altitude engine model with specific engine performance values, based on Rocketdyne acceptance test data. As a result of these differences the Atlas total propellant flow rate for the GD/A trajectory was an average of 13 lb/sec less than the STL n-stage trajectory. Approximately 75 percent of this flow rate difference is attributable to GD/A using nominal engine class, rather than specific engine performance. The remaining 25% of the flow rate difference is due to the inability of the sea level sustainer model to properly predict the variation of sustainer performance during booster phase. The Propulsion Laboratory concurs with the STL n-stage propulsion simulation.